Acta Œcologica
Œcol. Applic., 1986, Vol. 7, n° 4, p. 389-402.

Effects of different ectomycorrhizal fungi on growth of larch, Douglas fir, Scots pine and Norway spruce seedlings in fumigated nursery soil

F. Le Tacon and D. Bouchard
I. N. R. A., Centre de Recherches Forestières,
Laboratoire de Microbiologie Forestière, Champenoux, 54280 Seichamps, France.

ABSTRACT

Larch, Douglas fir, Scots pine and Norway spruce seedlings were inoculated with thirteen strains of ectomycorrhizal fungi after soil fumigation. Two *Laccaria laccata* isolates and one isolate of *Hebeloma crustuliniforme* formed abundant mycorrhizae with the four tree species and greatly stimulated seedling growth, excepted for that of larch, during the first two years. Production of plantable Douglas fir seedlings with well developed *Laccaria* mycorrhizae was obtained after two years, instead of the three or four years usually needed without fumigation and without mycorrhizal inoculation.

Key-words: *Ectomycorrhizae - Inoculation - Growth - Coniferous - Seedlings.*

RÉSUMÉ

Des semis de mélèze d'Europe, de Douglas, d'épicea commun et de pin sylvestre ont été inoculés par 13 souches de champignons ectomycorhiziens après désinfection du sol. Deux souches de *Laccaria laccata* et une souche d'*Hebeloma crustuliniforme* forment d'abondantes mycorhizes avec les 4 espèces et stimulent fortement la croissance des semis pendant les deux années de pépinière, excepté avec le mélèze d'Europe. Des semis de Douglas pouvant être transplantés en forêt ont été obtenus en deux ans au lieu des trois ou quatre habituellement nécessaires sans désinfection du sol et sans inoculation mycorhizienne.

Mots-clés : *Ectomycorhizes - Inoculation - Croissance - Résineux - Semis.*

INTRODUCTION

In forest nurseries, fumigants, fungicides, or heavy fertilization can reduce or eradicate inoculum in soil and cause a deficiency of mycorrhizae on seedlings. To correct this, inoculation with pure mycelial cultures of ectomycorrhizal fungi has often been recommended (Mikola, 1970; Trappe, 1977; Marx *et al.*, 1977, 1978, 1984; Molina, 1979, 1980, 1982; Shaw *et al.*, 1982; Molina & Chambard, 1983; Thomas & Jackson, 1983; Le Tacon *et al.*, 1983). The most important step in any nursery inoculation programme is the selection of the inoculant fungi (Marx, 1980). We know very little about suitable fungal species for pure culture inoculation. Species and even strains of the same species of ectomycorrhizal fungi differ in their effect upon growth of tree seedlings in the nursery and subsequent survival and growth after transplanting (Marx *et al.*, 1977). The purpose of this study was to determine in a fumigated nursery soil the effects of different fungi on mycorrhizal development and seedling growth of Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, Norway spruce, *Picea abies* (L.) Karst, larch, *Larix decidua* Miller and Scots pine, *Pinus sylvestris* (L.).

© Gauthier-Villars

TABLE I. — *Year of isolations, location and associated hosts of the strains used to inoculate the seedlings.*

Species	Isolate	Year of isolation	location	associated host	collected by
Laccaria laccata (Scop. ex Fr.) BK. and Br.	S 238 A	1978	Bent Co OR USA	*Larix occidentalis*	MOLINA
Laccaria laccata (Scop. ex Fr.) BK. and Br.	S 233	1976	Crater lake National Park	*Tsuga mertensiana*	MOLINA and TRAPPE
Hebeloma crustuliniforme (Bull. ex Fr.) Quél.	S 166	1971	Woods Creek Rd. OR USA	*Pseudotsuga menziesii*	TRAPPE
Hebeloma crustuliniforme (Bull. ex Fr.) Quél.	SIV	1974	Sivrite France	*Picea abies*	KIFFER
Hebeloma crustuliniforme (Bull. ex Fr.) Quél.	BR 21	1964	Alpes France	*Picea abies*	BRUCHET
Hebeloma cylindrosporum	BR	1970	Landes France	*Pinus pinaster*	BRUCHET
Paxillus involutus (Batsch) Fr.	Litt 1034	"	Wash. USA		LITTKE
Paxillus involutus (Batsch) Fr.	QBC	1981	Laurentides Natural Park, Canada	*Picea glauca*	GARBAYE
Hebeloma edurum Metrod	BR 14	1963	Alpes France	*Picea abies*	BRUCHET
Suillus bovinus (L. ex Fr.) O Kuntze	STH	1979	Ste Hélène Vosges France	*Pinus sylvestris*	LE TACON and GARBAYE
Pisolithus tinctorius	spores	1981	Douai France	*Betula pendula*	GARBAYE
Hebeloma circinans Quélet	BR 10	1963	Alpes France	*Picea abies*	BRUCHET
Suillus granulatus (L. ex Fr.)	S 101		Alpes suisses	*Pinus sylvestris*	FROIDEVAUX

MATERIAL AND METHODS

Inoculum preparation

Thirteen isolates were used (table I). Each isolate was grown in a vermiculite peat-moss nutrient mixture for 2 months at 25° C, using techniques described by MARX & BRYAN (1975). The inoculum was then stored no longer than one month at 5° C before use.

Nursery soil management

The experiment was installed in 1982 in the Peyrat-le-Château nursery (Haute-Vienne, France). The soil was a brown podzolic soil developed on granite and chemically improved by ten years of intensive fertilization. Chemical analyses are summarized in table II. The soil was disced during the winter 1981-1982, formed into nursery beds and fumigated with methyl bromide in April 1982. No fertilizer was applied in 1982.

TABLE II. — *Chemical analysis of the nursery soil*
(phosphorus was extracted with NaOH M/10 and H_2SO_4 M/250).

Organic matter %	Total C %	Total N %	C/N %	pH in water	Exchangeable cations in m.e./100 g Ca	K	Mg	P_2O_5 %
7.4.	4.3.	0.33	13.01	5.6	4.2	0.45	1.03	0.50

Plot installation

The experiment comprised fifty-six plots of one square metre. The experimental design was a randomized block with four replicates. Two litres of non-leached inoculum were incorporated per square metre into the upper 10 cm of soil with handtools in early May 1982. In the control plots nothing was incorporated into the soil. Each plot was divided in four parts and each part was then planted with non-treated Douglas fir, Norway spruce, larch or Scots Pine seeds. The seedlings were maintained two years in each plot.

Measurements

In November 1982, five seedlings of each species were chosen at random from each plot and lifted. The degree of ectomycorrhizal development was estimated visually for the inoculated fungus and for the naturally occurring ectomycorrhizal fungi (*Thelephora terrestris* and *Boletus* sp.) as follows:

0. No mycorrhizae,
1. Some mycorrhizae.
2. Mycorrhizae on less than half of the root tips.
3. Mycorrhizae on more than half of the root tips.
4. Mycorrhizae on almost all the root tips.
5. All short roots with mycorrhizae.

A mycorrhizal index was calculated for each fungus by dividing the sum of the scores by the number of seedlings. In November 1983 we only checked each plot to see if the inoculated fungus was still present. Height of all seedlings was measured in November 1982 and November 1983. Throughout this paper growth will be considered synonymous with seedling height. All data were processed by analysis of variance and the least significant difference was calculated at $P = 0.05$ and $P = 0.01$, according to Dunnett's test (DUNNETT, 1964).

RESULTS

ECTOMYCORRHIZAL FORMATION (table III)

First year

The two strains of *Laccaria laccata* and two strains of *Hebeloma crustuliniforme* (S 166 and S IV) formed abundant ectomycorrhizae with the four host species, often colonizing entire feeder root systems, except with larch. *Hebeloma cylindrosporum*, *Pisolithus tinctorius* and *Paxillus involutus* QBC also formed mycorrhizae with the four host species, but colonized only about half of the root tips. Larch and Douglas fir formed fewer mycorrhizae with these three fungal strains than did Scots pine or Norway spruce. *Hebeloma crustuliniforme* BR 21, *Hebeloma circinans* and *Hebeloma edurum* formed mycorrhizae only with Scots pine and Norway spruce, and the incidence was very low. *Suillus granulatus*, *Suillus bovinus* and *Paxillus involutus* Litt did not form any ectomycorrhizae. The naturally occurring fungus *Thelephora terrestris* had reinfested the fumigated soil only when the inoculated ectomycorrhizal fungi had not consistently formed mycorrhizae.

Second year

Two years after inoculation *Thelephora terrestris* had reinfested all the plots. Another naturally occurring fungus had partly colonized the root systems of larch in all the treatments. Although it did not produce sporocarps, we assumed that, based on mycorrhizal morphology, this unidentified fungus was *Suillus grevillei* (Klotzsch) Sing. In all the plots, the root system of Douglas fir seedlings was also partly colonized by *Suillus* type mycorrhizae. This fungus has not been identified. Examination of the four seedling species showed that although *Thelephora terrestris* or *Suillus grevillei* or *Suillus* sp. mycorrhizae were present, mycorrhizae formed by the previously inoculated fungi were also still present.

SEEDLING GROWTH

Larch (table IV and table V)

The first year, large differences in seedling height followed inoculation, but only seedlings inoculated with *Laccaria laccata* S 238 A and S 238 were significantly taller than the control seedlings which were partly contaminated with *Thelephora terrestris*. *Pisolithus tinctorius* and *Hebeloma crustuliniforme* were very successful in colonizing the short roots, but did not significantly increase seedling height in comparison with the control. In the second year, seedling height did not differ significantly between the treatments.

Douglas fir (table VI and table VII)

In the first year, the largest seedlings were obtained from inoculation with the two *Laccaria* isolates. *Paxillus involutus* Litt., which did not form mycorrhizae with Douglas fir had a significant effect on seedling height. *Hebeloma crustuliniforme*, which formed abundant ectomycorrhizae did not increase seedling height. In the second year, the best strains were still the two *Laccaria* isolates. *Paxillus involutus* Litt., which stimulated height in the first year without forming mycorrhizae, no longer affected it in the second year.

TABLE III. — *Ectomycorrhizal development of Scots pine, Norway spruce, Douglas fir and larch of one year seedlings in inoculated nursery soil.*
i. f. = inoculated fungus ; T. t. = Thelephors terrestris.

	Scots pine		Norway spruce		Douglas fir		European larch	
	i.f.	T.t.	i.f.	T.t.	i.f.	T.t.	i.f.	T.t.
Laccaria laccata S 238 A	4.5	0	4.0	0	4.5	0	3.2	0
Laccaria laccata S 238	3.7.	0	4.0	0	4.3	0	3.6	0
Hebeloma crustuliniforme S 166	4.9	0	4.8	0	4.8	0	3.0	0
Hebeloma crustuliniforme SIV	4.6	0	4.0	0	3.6	0	3.3	0
Paxillus involutus QBC	1.7	0.4	3.7	0.7	1.7	0.4	1.7	0.5
Hebeloma cylindrosporum	4.1	0	2.0	1.4	1.5	0	2.1	0
Pisolithus tinctorius	4.6	0	3.3	0	0.6	0.6	3.6	0
Hebeloma crustuliniforme BR 21	3.2	0	1.5	1.0	0	0.2	0.2	0
Hebeloma circinans	1.5	2.2	2.2	2.2	0	0.5	0.7	0.2
Hebeloma edurum	0.5	2.2	0.2	3.0	0	1.0	0	0
Paxillus involutus LITT	0	0.5	0	3.5	0	0.5	0	2.3
Suillus granulatus	0	1.5	0	3	0	0	0	0.5
Suillus bovinus	0	2.7	0	2.0	0	0.5	0	0.7

TABLE IV. — *Growth and ectomycorrhizal development of larch seedlings inoculated with different fungal strains. First year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (mm)	Increase in height compared to the control (in %)	*Thelephora* index	Inoculated fungus index
Laccaria laccata S 238 A	70.26	320	0	3.2
Laccaria laccata S 238	63.57	280	0	3.6
Hebeloma crustuliniforme S 166	46.49		0.3	3.0
Hebeloma cylindrosporum P	43.68		0	2.1
Paxillus involutus QBC	38.47		0.5	1.7
Hebeloma edurum	33.50		0	0
Hebeloma crustuliniforme SIV	31.99		0	3.3
Suillus bovinus ST4	31.80		0.7	0
Pisolithus tinctorius	31.31		0	3.6
Paxillus involutus Litt.	27.43		2.3	0
Hebeloma crustuliniforme BR 21	24.61		0	0.2
Hebeloma circinans	20.49		0.2	0.7
Suillus granulatus	18.46		0.5	0
Control	16.70		0.5	

Least significant difference according to Dunnett's test

Level 5 %	41.54
Level 1 %	50.58

TABLE V. — *Growth of larch seedlings inoculated with different fungal strains. Second year. Bars indicate treatments that were not significantly different at the 5 % level.*

	height (cm)
Laccaria laccata S 238	27.69
Hebeloma crustuliniforme S 166	27.56
Hebeloma cylindrosporum	27.16
Hebeloma crustuliniforme BR 21	25.43
Hebeloma edurum	23.42
Control	21.01
Hebeloma crustuliniforme SIV	20.82
Laccaria laccata MOL	20.24
Suillus granulatus	18
Hebeloma circinans	17.91
Pisolithus tinctorius	17.43

Least significant difference according to Dunnett's test

Level 5 %	N.S.
Level 1 %	N.S.

Scots pine (table VIII and table IX)

In the first year four strains stimulated seedling height significantly. All the strains formed ectomycorrhizae with Scots pine seedlings.

The best isolates were *Laccaria laccata* S 238 A, *Hebeloma cylindrosporum* and *Hebeloma crustuliniforme* S 166. In the second year only *Laccaria laccata* S 238 significantly affected seedling height.

Norway spruce (table X and table XI)

One isolate significantly increased the height of Norway spruce seedlings the first year, compared with two in the second year. These two strains were the two *Laccaria laccata* isolates.

DISCUSSION AND CONCLUSION

In fertilized nursery soil at Peyrat-le-Château coniferous seedlings grew very badly after soil fumigation. The naturally occurring ectomycorrhizal fungus *Thelephora terrestris* reinvaded the fumigated plots to some extent during the first year, and more completely during the second. After recolonization by *Thelephora*

TABLE VI. — *Growth and ectomycorrhizal development of Douglas fir seedlings inoculated with different fungal strains. First year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (mm)	Increase in height compared to the control in %	*Thelephora* index	Inoculated fungus index
Laccaria laccata S 238 A	68.87	80.7	0	4.5
Laccaria laccata S 238	55.64	50.4	0	4.3
Paxillus involutus Litt.	53.98	45.9	0.5	0
Suillus granulatus	51.26		0	0
Hebeloma circinans	50.53		0.5	0
Suillus bovinus	49.95		0.5	0
Hebeloma crustuliniforme S 166	48.61		0	4.8
Paxillus involutus QBC	47.79		0.4	1.7
Pisolithus tinctorius	45.68		0.6	0.6
Hebeloma crustuliniforme BR 21	44.16		0.2	0
Hebeloma crustuliniforme SIV	43.56		0.3	3.6
Hebeloma edurum	42.52		1	0
Hebeloma cylindrosporum	42.13		0	1.5
Control	37.00		0.5	

Least significant difference according to Dunnett's test
level 5 % 15.09
level 1 % 18.37

terrestris seedling growth was improved and was always better than in non-fumigated soils because fumigation had destroyed soil-borne pathogens (LE TACON *et al.*, 1985). In the first year after soil fumigation only a recolonization by *Thelephora terrestris* was observed. This recolonization started three to four months after fumigation. In the second year, Larch seedlings became infected by another naturally occurring ectomycorrhizal fungus, probably *Suillus grevillei*, which coexisted with *Thelephora terrestris*. In the second year, roots of Douglas fir seedlings were also mycorrhizal with another naturally occurring fungus, probably also belonging to the genus *Suillus*.

TABLE VII. — *Growth of Douglas fir seedlings inoculated with different fungal strains. Second year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (cm)	Increase in height compared to the control (in %)
Laccaria laccata MOL	28.36	66.7
Laccaria laccata S 238	27.57	62.8
Hebeloma crustuliniforme S 166	23.33	
Hebeloma crustuliniforme SIV	22.14	
Pisolithus tinctorius	21.77	
Hebeloma cylindrosporum	20.82	
Hebeloma edurum	20.39	
Hebeloma crustuliniforme	20.34	
Hebeloma circinans	20.32	
Paxillus involutus QEC	20.29	
Suillus granulatus	19.75	
Control	17.01	
Least significant difference according to Dunnett's test		
Level 5 %	8.05	
Level 1 %	9.86	

Inoculation with pure cultures of ectomycorrhizal fungi increased seedling height, compared to natural recolonization by *Thelephora terrestris*. The two *Laccaria laccata* isolates and one isolate of *Hebeloma crustuliniforme* (S 166) formed abundant mycorrhizae with the four tree species. This stimulation continued in the second year for all species except Larch. The natural recolonization of the soil by *Suillus grevillei*, obscured the responses observed in larch during the first year after inoculation. For growth of Norway spruce and Douglas fir, both strains of *Laccaria laccata* were equally efficient whereas only one of these strains was efficient with Scots pine.

TABLE VIII. — *Growth and ectomycorrhizal development of Norway spruce seedlings inoculated with different fungal strains. First year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (mm)	Increase in height compared to the control (in %)	*Thelephora* index	Inoculated fungus index
Laccaria laccata S 238 A	53.94	83	0	4.5
Hebeloma cylindrosporum	45.76	55.4	0	4.1
Hebeloma crustuliniforme S 166	45.61	54.9	0	4.9
Paxillus involutus QBC	43.83	48.9	0.4	1.7
Hebeloma circinans	43.35		2.2	1.5
Pisolithus tinctorius	43.04		0	4.6
Laccaria laccata S 238	40.69		0	3.7
Suillus bovinus	39.79		2.7	0
Paxillus involutus Litt.	38.54		0.5	0
Hebeloma crustuliniforme SIV	36.25		0	4.6
Suillus granulatus	34.20		1.5	0
Hebeloma crustuliniforme BR 21	31.47		0	3.2
Hebeloma edurum	31.41		2.2	0.5
Control	29.43			
Least significant difference according to Dunnett's test				
level 5 %	14.20			
level 1%	17.28			

TABLE IX. — *Growth of Scots pine seedlings inoculated with different strains. Second year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (cm)	Increase in height compared to the control (in %)
Laccaria laccata S 238 A	18.43	62.7
Hebeloma cylindrosporum	15.70	
Hebeloma crustuliniforme SIV	14.70	
Hebeloma circinans	13.65	
Hebeloma crustuliniforme S 166	12.60	
Paxillus involutus QBC	12.40	
Laccaria laccata S 238	12.90	
Pisolithus tinctorius	12.20	
Suillus granulatus	11.70	
Control	11.33	
Hebeloma edurum	10.91	
Hebeloma crustuliniforme L.	10.84	
Least significant difference according to Dunnett's test		
Level 5 %	4.55	
Level 1 %	5.58	

Different strains of *Hebeloma crustuliniforme* were not efficient, although they formed abundant mycorrhizae.

EK *et al.* (1983) showed that *Laccaria laccata* produces growth substance, which may be responsible for its growth stimulating effect (TYMINSKA *et al.*, 1985). Our results differ from those of SHAW *et al.* (1982), MOLINA & CHAMARD (1983), THOMAS & JACKSON (1983), who successfully inoculated container-grown Douglas fir and Sitka spruce seedlings with *Laccaria laccata*, but did not obtain improved growth and sometimes observed growth depression. Our positive results may be related to the large volume of soil explored by the roots of field grown plants compared to that of containerized seedlings.

Douglas fir seedling growth was significantly improved in the first year by inoculation with *Paxillus involutus* Litt., which, however, failed to form mycorrhizae. This effect of free-living mycelium in soil was shown for the first time on Sitka spruce with *Rhizopogon luteolus* (LEVISOHN, 1956).

The most important practical result of this study is the demonstration that plantable Douglas fir seedlings can be produced in a fumigated soil after two years with the aid of inoculation using *Laccaria laccata* as the mycorrhizal symbiont. Without such inoculation, three to four years are usually needed in France to obtain plantable seedlings.

TABLE X. — *Growth and ectomycorrhizal development of Norway spruce seedlings inoculated with different fungal strains. First year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (mm)	Increase in height compared to the control (in %)	Thelephora index	Inoculated fungus index
Laccaria laccata S 238 A	34.28	45.0	0	4.0
Laccaria laccata S 238	32.70		0	4.0
Suillus bovinus	32.70		3.0	0
Paxillus involutus QBC	32.29		0.7	3.7
Hebeloma crustuliniforme S 166	31.88		0	4.8
Suillus granulatus	30.26		2.0	0
Hebeloma circinans	29.97		2.2	0.7
Hebeloma crustuliniforme STV	28.33		0.6	4.0
Hebeloma edurum	28.00		3.0	0.2
Paxillus involutus Litt.	27.21		3.5	0
Hebeloma cylindrosporum	25.33		1.4	2.0
Hebeloma crustuliniforme BR 21	25.00		1.0	1.5
Pisolithus tinctorius	24.41		0	3.3
Control	23.63		1.4	

Least significant difference according to Dunnett's test

Level 5 %	9.73
Level 1 %	11.86

TABLE XI. — *Growth of Norway spruce seedlings inoculated with different fungal strains. Second year. Bars indicate treatments that were not significantly different at the 5 % level.*

	Height (cm)	Increase in height compared to the control (in %)
Laccaria laccata	12.72	43.4
Laccaria laccata S 238	11.71	32.0
Hebeloma crustuliniforme S 166	11.36	
Hebeloma crustuliniforme SIV	11.15	
Pisolithus tinctorius	10.10	
Paxillus involutus QBC	9.87	
Hebeloma circinans	9.51	
Suillus granulatus	9.44	
Hebeloma edurum	9.31	
Control	8.87	
Hebeloma crustuliniforme L.	8.61	
Hebeloma cylindrosporum	8.33	

Least significant difference according to Dunnett's test

Level 5 %	2.68
Level 1 %	3.28

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Barbara MOSSE for reviewing the manuscript.

We express our thanks to Dr. R. MOLINA, Dr. J. TRAPPE, Dr. G. BRUCHET, Dr. L. FROIDEVAUX, Dr. W. R. LITTKE, Dr. E. KIFFER and Jean GARBAYE for the ectomycorrhizal isolates.

Also, the authors acknowledge technical assistance of Mr. TEXIER and Mr. NYS (Nursery of Peyrat-le-Château).

REFERENCES

DUNNETT C. W., 1964. — New tables for multiple comparisons with a control. *Biometries*, **2**, 482-491.

EK M., LJUNQUIST P. D. & STENSTROM E., 1983. — Indole-3-acetic acid production by mycorrhizal fungi determined by gas-chromatography-mass spectrometry. *New Phytologist*, **94**, 401-407.

LE TACON F., JUNG G., MICHELOT P. & MUGNIER J., 1983. — Efficacité en pépinière forestière d'un inoculum de champignon mycorhizien produit en fermenteur et inclus dans une matrice de polymères. *Ann. Sci. For.*, **4**, 2, 165-176.

LE TACON F., BOUCHARD D. & PERRIN R., 1985. — Effects of soil fumigation and inoculation with pure culture of *Hebeloma cylindrosporum* on survival, growth and ectomycorrhizal development of Norway spruce and Douglas fir seedlings. *Europ. J. For. Pathol.*

LEVISOHN I., 1956. — Growth stimulation of forest tree seedlings by the activity of free-living mycorrhizal mycelia. *Forestry*, **29**, 53-59.

MARX D. H., 1980. — Ectomycorrhizal fungus inoculation: a tool for improving forestation practices. In: MIKOLA P., ed., *Tropical mycorrhiza research*. Clarendon Press, Oxford, p. 13-71.

MARX D. H. & BRYAN W. C., 1975. — Growth and ectomycorrhizal development of loblolly pine seedlings in fumigated soil infested with the fungal symbiont *Pisolithus tinctorius*. *Forest Sci.*, **22**, 91-100.

MARX D. H., BRYAN W. C. & CORDELL C. E., 1977. — Survival and growth of pine seedlings with *Pisolithus* ectomycorrhizal after two years on reforestation sites in North Carolina and Florida. *Forest Sci.*, **23**, 363-373.

MARX D. H., MORRIS W. G. & MEXAL G. M., 1978. — Growth and ectomycorrhizal development of loblolly pine seedlings in fumigated and non-fumigated soil infested with different fungal symbionts. *Forest Sci.*, **24**, 193-203.

MARX D. H., CORDELL C. E., KENNEY P. S., MEXAL J. G., ARTMAN J. D., RITTLE J. W. & MOLINA R. J., 1984. — Commercial vegetative inoculum of *Pisolithus tinctorius* and inoculation techniques for development of ectomycorrhizae on bare-root tree seedlings. *Forest. Sci. Monograph.*, **75**, 1-10.

MIKOLA P., 1970. — Mycorrhizal inoculation in afforestation. *Inst. Rev. For. Res.*, **3**, 123-196.

MOLINA R., 1979. — Ectomycorrhizal inoculation of containerized Douglas-fir and lodgepole pine seedlings with six isolates of *Pisolithus tinctorius*. *For. Sci.*, **25**, 385-590.

MOLINA R., 1980. — Ectomycorrhizal inoculation of containerized western conifer seedlings. *U. S. D. A., For. Serv. Res. Note*, PNW-357.

MOLINA R., 1982. — Use of the ectomycorrhizal fungus *Laccaria laccata* in forestry. I. Consistency between isolates ineffective colonization of containerized conifer seedlings. *Can. J. For. Res.*, **12**, 469-473.

MOLINA R. & CHAMARD J., 1983. — Use of the ectomycorrhizal fungus *Laccaria laccata* in forestry. II. Effects of fertilizer forms and levels on growth of container-grown Douglas fir and ponderosa pine seedlings. *Can. J. For. Res.*, **13**, 89-95.

SHAW C. G., MOLINA R. & WALDEN J., 1982. — Development of ectomycorrhizae following inoculation of containerized Sitka and white spruce seedlings. *Can. J. For. Res.*, **12**, 191-195.

THOMAS G. W. & JACKSON R. M., 1983. — Growth responses of Sitka spruce seedlings to mycorrhizal inoculation. *New Phytologist*, **95**, 223-229.

TRAPPE J. M., 1977. — Selection of fungi for ectomycorrhizal inoculation in nurseries. *Ann. Rev. Phytopathol.*, **15**, 203-222.

TYMINSKA A., LE TACON F. & CHADŒUF J., 1985. — Effect of several ectomycorrhizal fungi on *Pinus sylvestris* seedlings at increasing phosphorus levels in the medium. *Can. J. Botany*.